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PROJECT SERE: AN OUTLINE OF THE NATURAL RESOURCES REMOTE SENSING RESEARCH PROGRAM

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Project SERE

A Research Program Outline for Remote Sensing of Natural Resources

J. B. MACHADO

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The present report, based on work done at CNAE, is part of the study and research program of the Space Physics Laboratory on Remote Sensing (SERE).

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This publication is authorized by the undersigned.

/s/
Fernando de Mendonca
Scientific Director

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J. B. Machado

ABSTRACT: This report introduces the concept of remote sensing; describes briefly the present state of the art in the U. S. A., gives preliminary equipment lists, suggests a distribution of personnel available and establishes criteria for test site selection, suggesting some locations in Brazil. It will serve as a basis for the working sessions at the conclusion of phase A of the CNAE-NASA Cooperative Program, to take place at NASA-MSC-Houston, in July 1968.

I - Initial Considerations

A research program of this type can assume widely different directions. /1*
The mode of its implementation and direction can vary from one which requires profound scientific observation and development of complex sensory systems to one in which simple appraisals with currently operational sensors are performed. It can run from the study of minute details pertaining to spectral properties of a given material (to provide data for the search of most adequate technology for its detection) to elementary image analysis in spectral regions selected at random. In any case, in its entirety, the program obviously will be adjusted in accordance with the money and talent available in the research organization.

Irrespective of the mode of attack, this research will always be oriented towards answering the same question: does there exist some observable characteristic of reflected or emitted electromagnetic radiation by an object which helps to deduce that what is sought about it? For example, can the agronomist identify the species of vegetation, determine its vigor, or recognize undesirable conditions of salinity or humidity, knowing that none of these properties can be directly measured by the sensor?

Not withstanding that, the remote aerial sensor can be a device relatively simple and cheap whereas the research effort, in its entirety, may require instrumentation less modest. There is a need for laboratory study to allow com- /2
prehension of the interaction between radiation and matter. In these studies, one can be interested, for example, in spectral transmittance and reflectance of leaves of some plant and their variation due to given ambient conditions such as solar light, temperature, humidity, and type of soil.

Consequently, field observations are indispensable for verification of laboratory phenomena. Can a field soil be classified on the basis of spectral properties

*Numbers in the margin indicate pagination in the foreign text.

that are similar to the ones employed in the laboratory? Can the geometry of solar illumination, natural soil constitution or ambient conditions modify the spectral properties? Can a variation in these natural factors reduce the probability of correct interpretation?

Finally, there is an intense need for experimentation of aerial detection before a sensor can be used for obtaining practical data. This experimentation will allow the observation of conditions (angles of observation and illumination) minutely different from those to be encountered during the operational phase. It will also be required for the collection of data pertaining to regions of difficult accessibility (the top of a grove, for example). Another advantage is that it will permit significant statistical samplings particularly useful during the appraisal of the level of confidence of the sensory technique. Laboratory and field measurements could show how easy is the detection of a particular phenomena or characteristic; however, the degree of practical application will remain dependent on the existence, or non-existence, of phenomena masking similar characteristics and occurring naturally in an environment. This requires the collection of data from large areas. Large volumes of data will require appropriate processing compatible with the given volume.

The aerial instrumentation may vary from a manual photographic camera, carried in a small plane, to an elaborate system comprising radiometers, spectral radiometers and imagers (displays), operating practically over the entire spectrum of electromagnetic radiation and transported by a powerful four-engine plane (as in the case of the NASA program). /3

In summary, the research work on remote sensing for the survey of natural resources can vary from quiet laboratory measurements to laborious collection of data with an aircraft, followed by complicated computer analysis. After considering human and material availabilities, the important aspect is to have well defined program objectives, with the research tasks aimed at the attainment of these objectives. Having determined the tasks, all other aspects fall into place, and the requirements for instrumentation, laboratory, test sites and aircraft become evident.

II - Program Objectives

In compliance with the cooperation plan CNAE-NASA, the program has the following objectives:

a) Development of techniques and systems of acquisition, interpretation and utilization of data obtained by aircraft, concerning terrestrial resources in Brazil in such a manner as to allow the determination of their potential utility in spacecraft applications;

b) Contribute to Brazilian and American competence in a progressive technology, where the aim would be to find and extend the scientific applications and the in-depth utilization of this technology;

c) Provide additional data on experiments and scientific and technical research useful towards the development of techniques for the survey of terrestrial resources; /4

d) Familiarize Brazilian personnel with the acquisition, processing, reduction and analysis of data collected by remote sensors;

e) Identify promising applications in Brazil from data concerning terrestrial resources obtained by means of remote sensors;

f) Develop compatible systems of data management for easy exchange between the United States and Brazil.

It is clear that the intention of Brazilian researchers is to attack the problem with a consideration towards its fundamental scientific research. This is despite the possible impression given by the text of the Plan of Cooperation, in its description of elementary tasks, that the project will consist exclusively of a comparison of aerial data registered by operational sensors with a well-established "truth in soil," the purpose being to discover "keys" of interpretation for generalized use or other statements. In that case, this research would reduce to a mere appraisal of the applicability of remote sensors of proven efficiency for other regions, with due respect for the peculiarities of our natural environment.

The state of the development of the art does not allow the restriction towards the latter mode of operation. In fact, the cooperative program allows our researchers the possibility of making a scientific contribution.

Nothing is sealed in the program as far as the considered areas of scientific investigation are concerned; however, the adopted composition of our Team of Researchers assumes work on the same disciplines that NASA is interested in.

Further, there exists complete freedom of initiative; however, for the purpose of facilitating the exchange of technical and scientific data, primarily of particular interest to Brazil, the phase dealing with orbital sensing does provide for the establishment of a system of registering, acquisition, processing, protection and distribution of data compatible with the one adopted by the United States. /5

In summary, the program, under coordination and control of CNAE, will have the following specific objective:

Develop remote sensing methods for multi-spectral characterization of natural resources.

To attain this objective, the research will cover three intimately related study areas;

a) Basic studies in the laboratory and field, aimed at:

- Better knowledge of the interactions between electromagnetic radiation and matter, and factors which influence these phenomena;
- Definition of informational requirements for ultimately surveying specific resources;
- Determination of the optimal spectral bands for these ends;
- Determination of the viability of the corresponding experimental study.

b) Experimental studies of multi-spectral sensing utilizing data registered on board an aircraft over test areas sufficiently known, aimed at:

- Verifying the adequacy of basic studies through the analysis of registered data;
- Developing norms for the interpretation of data;
- Establishing a system of classifying natural resources that were surveyed; /6
- Determining the degree of reliability of the above classification system.

c) Studies of processing and interpretation of data, aimed at (given its great volume):

- Development of systems for rapid reduction and processing of data;
- Development of systems for rapid interpretation of the results.

III - Availability of Resources

Human Resources

For consultation and advice, there exists a group consisting of representatives of the following organizations interested in the project:

- National Research Council
- General Staff of the Armed Forces
- Department of Aeronautics
- Department of Foreign Relations
- Department of Agricultural Research and Experimentation, of the Department of Agriculture
- Agricultural Secretariat of the State of S. Paulo
- National Department of Work and Sanitation, of the Department of Interior
- Brazilian Institute of Forest Development
- Brazilian Institute of Agrarian Reform
- Brazilian Institute of Geography and Statistics
- National Department of Mineral Production and /7
- National Branch of Waters and Energy, of the Department of Mines and Energy
- Petroleum
- Directorate of Hydrography and Navigation
- Institute of Marine Research, from the Marine Department
- Directorate of Geographic Service, Department of the Army
- National Association of Aerophotogrametric Enterprises

For executive tasks CNAE has, at the moment, an initial team of researchers, participating in an apprenticeship at ERAP (Earth Resources Aircraft Program) of the M.S.C. (Manned Spacecraft Center) in Houston, Texas, consisting of 12 individuals whose distribution by disciplines is: 2 agronomers, 1 geologist, 1 hydrologist, 1 geophysicist, 2 oceanographers, 1 geographer, and 4 electronic engineers (computation and instrumentation). The first 8 belong to organizations outside of CNAE, which are expected to maintain this personnel at CNAE's disposal for the first two years of the project.

Beyond this research personnel, there are four CNAE researchers on a doctorate program in Systems Engineering at Stanford University, in California, who are also interested in the Remote Sensing Project.

For coordination and control there is a Project Manager at CNAE and a Manager for Mineral Resources at the National Department of Mineral Production. The latter is coordinating the researchers' apprenticeship with the exception of the instrumentation portion done at M.S.C.

In the CNAE, the following allocation of personnel for the project is anticipated (Quinquennial Plan): /8

Year	1968	69	70	71	72
Researchers	17	20	21	33	33
Technicians	1	5	10	10	10
Total	18	25	31	43	43

It is expected that concomitantly with the internal growth shown in the table, other organizations than CNAE, having interest in the Project, will produce a ramified development. In this sense, a course in Remote Sensors given by the initial group is being organized and will begin in September.

Material Resources

The Program-Estimate for the Quadrennium 1968-1971 foresees the following financial resources destined, exclusively, for the project:

Year	1968	69	70	71	Total
Thousand NCr$	601	6704	8505	9520	25330

Since there will be no exchange of funds between the teams of research of the two nations, all the expenses of CNAE, for the project, will remain within the above limits.

There is in the meantime a possibility at CNAE of using certain facilities of general utility (laboratory of electronics, computation, etc.) which dispose of personal financial resources. /9

Services which can be expected from other external parties interested in the project will, as a rule, be of nonfinancial nature.

IV - Aerial Instrumentation

Sensing Instrumentation

In order to facilitate the selection of instruments to be utilized by the CNAE program the following information summary on instruments, prepared from general characteristics furnished by NASA, as well as operational status and costs for aircraft instrumentation (Tables I and II), for tests sites (Tables III and IV) and for laboratories is given.

Sensors for optical electromagnetic radiation can be classified in two categories in accordance with band width detection:

A - Photographic cameras (0.3 to 1.0 microns)
B - Sensors of enlarged band (0.3 to 1.5 microns)

For the anticipated utilization category A contains:

1 - Metric cameras
2 - Multi-band cameras

Both utilize detectors consisting of photographic emulsions sensitive to the appropriate spectral radiation bands, beyond the visible, known as ultra-violet and infra-red. Metric cameras, given the existing geometrical characteristics, are generally used by the already classic topographical survey techniques: aerial /12
photography and photo-interpretation.

Multi-band cameras can exist within a single camera endowed with multiple lenses approaching (9) nine in number or in a cluster of (4) four cameras. These cameras take simultaneous photographs or pre-selected spectral bands depending on the combinations of films and filters which provide large volumes of additional information elements to the photo-interpreter. However, the use of color films, common or infra-red of false color, or black-white and multi-band filters in a single camera, produce photographs which can be considered to be multi-band.

Sensors of enlarged band, in the optical region from 0.3 to 15 microns, are of three primary types:

3 - Radiometers
4 - Spectrometers
5 - Displays (Imagers)

All use photoconductive or photovoltaic detectors, each one producing a different type of information and employed for distinct purposes. Calibrated radiometers

TABLE I

INSTRUMENTATION IN CONVAIR 240A-NASA 926

INSTRUMENT	SPECTRUM	RECORDING	BRAND-TYPE	COST, thousands of dollars	INSTALLATION
OPTICAL REGION					
Metric Camera	0.4 to 0.7μ	9" x 9" Film	WILD RC-8	21	Operational
Multiband Camera	0.3 to 0.9μ	70mm Film	ITEK-9 LENSES	65	"
Ultraviolet Imager	0.3 to 0.5μ	35mm Film	AAS-5-2 CHANNELS	GIVEN USAF	"
Infrared Imager	8 to 14μ	70mm Film	RECONOFAX-IV	"	"
MICROWAVE REGION					
Radar Scatterometer	13.3 GHz	Magnetic Tape	RYAN	125	"
Microwave Radiometer	9.3 GHz 15.8 GHz 22.2 GHz 34.0 GHz	"	JPL MR62-MR64	300	"

TABLE II

INSTRUMENTATION IN LOCKHEED ELECTRA NP-3A, NASA 927

INSTRUMENT	SPECTRUM	RECORDING	BRAND-TYPE	COST, thousands of dollars	INSTALLATION
OPTICAL REGION					
1. Metric Camera (2)	0.4 to 0.7μ	9" x 9" Film	WILD RC-8	42	Operational
2. Multiband Camera Cluster (5)	0.4 to 1μ	5" Film	CHICAGO-AERIAL	130	August 1968
3. Infrared Radiometer	10 to 12μ	Magnetic Tape	BLOCK	100	"
4. Infrared Spectrometer	6.5 to 13μ	"	LOCKHEED	150	"
5. Dual Channel Imager Display	0.3 to 5.5μ and 8 to 14 μ	70mm Film and Magnetic Tape	BENDIX, or TEXAS	250	November 1968
6. Laser Altimeter	6349 Å	Magnetic Tape	CONTROL DATA, or TRG, or HONEYWELL	300	?
MICROWAVE REGION					
7. Sidelooking Radar	16.5 GHz	5" Film	PHILCO	250	August, 1968
8a. Radar Scatterometer	400 MHz	Magnetic Tape	EMERSON	275	Operational
8b. Radar Scatterometer	13.3 GHz	"	RYAN	125	"
9. Microwave Radiometer	1.4; 19.0; 22.26e 32.46 GHz	"	SPACE GENERAL	385	December 1968
10. Microwave Imager "Display"	8.9 to 9.9 GHz	70 mm Film	AUTONETICS	450	?

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are used for absolute measurements within energy bands due to emitted or reflected radiation, which are employed for inferring the states or processes existing in the objects situated within the field of vision of the collecting optical system.

Spectrometers produce information concerning the spectral distribution of radiation energy due to emission, reflexion, absorption and transmission which are used to infer the constitution of objects situated within the field of the optical system.

Imagers (displays) produce images in which the forms and tones are utilized for the detection and identification of objects within the area covered by the collecting optical system. Since there do not exist techniques, like those of the conventional photography, which sense in one sample the entire scene at the frequency of consideration, it is necessary to resort to instruments which, focus on /13 small elemental areas of the scene and then by means of regular sweeping from element to element form the entire image. Image resolution, therefore, is limited by the small instantaneous field of vision. Usually the optical collecting system explores a line transversal to the direction of flight and the aircraft's motion insures that the line of exploration transfers to successively adjacent positions.

The image so detected is displayed line by line on cathode ray tubes where it can be photographed. The selection of given wavelengths, within the study region, is obtained by means of a selection of detectors and interposition of filters. These instruments can be designed to produce simultaneous images in more than one spectral band and are usually constructed with two detection channels: one for the 0.3 to 5.5 microns band and the other for 8 to 14 microns, both provided with filtering devices (between 5.5 and 8 microns there exists a strong atmospheric absorption of infra-red radiation).

In principle, radar techniques can be applied in any part of the electromagnetic spectrum. This was done on the optical region by the use of "lasers" for the measurement of distances and altitudes of the greatest precision. The list of sensory instrumentation for NASA's Electra airplane has:

6 - Laser Altimeter

Besides its current use in topographical survey equipment and photogrammetric control it is expected that it will be an adequate sensor for oceanographic studies of the sea, wave propagation, and great doubtful depths.

Electromagnetic energy sensors in the microwave region utilize antennas and electronic circuits for detection and can be classified, in accordance with the origin of the captured energy, in two categories: /14

A - Active sensors or radars
B - Passive sensors

Radar (Radio Detection and Ranging) employs active, sensing techniques of electromagnetic energy for wavelengths beginning at 1 (one) mm up to several meters. The following aerial radars are anticipated for the project:

7 - Sidelooking radar
8 - Radar scatterometer

All radars are sensors of the returned fragments of energy pulses radiated by themselves. The emission of these pulses, of essentially pure frequency (monochromatic), along the direction of the area under investigation, is attained by means of a highly directional antenna which, in the majority of cases, is also used to capture the returned energy. Radar operation, therefore, is limited to its direct line of sight. All radars are provided with means of rigorous time interval fixation in such a manner as to allow precise determination of the distance to the attained surface. The intensity of the energy returned is, also, usually measured. The collection of data, in the case of a sidelooking radar, is obtained by means of an antenna laterally attached to the plane and oriented in such a manner as to produce a radiation axis perpendicular to the direction of flight as well as cover a wide band of terrain with respect to the aircraft advance. The representation is made with cathode ray tubes by means of lines synchronized to the emission of pulses and amplitude modulated by the distance and intensity information. The record is made with a photographic film which displaces along the display with a velocity proportional to the relative velocity of the plane with respect to the soil. Compensation of the distortion in perspective of the captured signals is possible with electronic processing. /15

The degree of azimuth resolution of the obtained images improves directly with the increase in antenna size and since the aerial equipment is eventually planned to be used in satellites, the instrument of high resolution to be used in NASA's airplane will be of "synthetic opening." This radar is so called because it operates as though it has an antenna of greater "synthetic" opening as compared to the actual physical dimensions.

This effect is attained by means of summing the return signals and making it appear as though the summed signal were emitted and captured at once by a long linear array of antennas which is created by the airplane movement.

The simulation of an antenna of great proportions provides great azimuth resolution. The utilization of very short transmitting pulses permit great distance resolution. In this manner it will be possible to map the soil, with the required resolution and a noteworthy contrast, through blankets of lighter clouds and independently of the illumination by natural radiation.

Sidelooking radars can transmit with antennas of vertical or horizontal polarization. In either case the return signals are received simultaneously and are of equal or crossed polarization to the transmitted. These signals are presented, side by side, with two images differentiated by diverse effects of depolarization which characterize the terrains.

Radars of the second type measure the scattering (and the reflection) of electromagnetic waves of its emission throughout the surfaces on which they fall. Like in the majority of equipments the transmitters and receivers of these radars are stationary and the majority of these sensors measure the intensity of the returned signals to the source. The major part of the captured return radiation is consequently of a scattered or diffused wave nature and only occasionally the portion reflected by a scattered surface (with small irregularities compared to the wavelength) represents a significant contribution. From this the Americans /16 decided to use the term "scatterometer" as more appropriate than "reflectometer;" in Portuguese, perhaps, it is preferable to use the term diffuser. The scattering radar measures the coefficient of soil scattering as a function of the angle of incidence of its peculiar radiation. This coefficient is a function of the geometry and dielectric properties of the surface hit by the radiation, and also of the frequency, polarization and angle of incidence of this radiation. It is proved that for a given frequency and polarization the representative scattering coefficient variation curves as a function of the angle of incidence, show forms, significantly different for different types of terrains and surface states.

Category B, passive sensors, comprises sensors of microwave electromagnetic energy of natural origin. It is well known that all bodies constantly emit radiation on a wide band of frequencies and polarizations as long as they are not at absolute zero (-273°C) and that, the total radiated energy at the energy in any spectral band (including microwaves) increases with the body temperature. This being the case it is possible to obtain, with microwave sensors, measures of temperature or, more specifically, measures of brightness of any source of radiant energy: "temperature of a black body having an identical surface brightness as the source of observation."

The following instruments are anticipated to be used on the project:

9 - Microwave radiometers
10 - Microwave displays (imagers)

The so called microwave radiometers, four in number in NASA's aircraft and operating at various frequencies, produce, in fact, information concerning spectral distribution of the observed emission. /17

The displays furnish surface temperature distribution maps with a +0.5°C precision. It is sought to enumerate, with these instruments, the observed microwave emissions with physical, chemical and geomorphological aspects of the terrain and the atmosphere.

It is not probable that these sensors, given their limitations, will redeem paper as relevant as the one generated by photographs, infrared radiation or radars. Nevertheless there exist problems, particularly those related to the distribution of waters on the terrestrial sub-surface, for which the contribution from radiometers and microwave displays perhaps will turn to be sufficiently significant.

Aircraft

The program conducted by NASA utilizes two airplanes: the first is the Convair 240 A used since 1964 and contains sensors shown in Table I. This airplane was pressurized for high altitude flights and is furnished with an auxiliary gas turbine generator for direct and alternating currents of 60 and 400 Hz. The second is a Lockheed Electra NP-3A and appears to be ideal for sensory experimentation up to 12000 meters of altitude. Since this aircraft was employed by the American Naval Aviation for anti-submarine patrol it came with the required instrumentation for navigation whose precision is perfectly adequate for the areas covered by the sensory program. It also was furnished with an auxiliary electric generator which allows its operation without auxiliary ground equipment. /18

Beyond the main instrumentation the following instruments are foreseen for the NP-3A:

- Radiation Thermometer
- Total temperature sensor probe
- Liquid water content probe
- Hygrometer

For recording sensed data, beyond photographic film, the following are utilized:

- Magnetic Tape Recorders, 1 MHz band, (AMPEX FR1600)
- Eight Channel Graphic Recorders (SANBORN)
- Thirty-two Channel Oscillographic Recorders, SKHZ, (VISICORDER)
- Memory Oscilloscopes, Double Trace

There exists an ASQ-90 ADAS (Auxiliary Data Annotation Set) for installation in the two planes. This device is used for compact annotation of a large number of important auxiliary information, on film negatives or magnetic tape, related to aerial data collection missions such as: mission number, date, hour, latitude, longitude, test site number, alignment, run, flight parameters, etc. It utilizes a binary coding scheme and, by means of computer processing and the use of a titler, it is possible to automatically print tites corresponding to each sensory record.

Aircraft types and respective cargoes used by the collaborating organizations are numerous and the performance requirements are sometimes modest. Thus, University of Michigan utilizes C-46's and C-47's (DC-3); the Naval Oceanographic Office, the C-54 Skymaster and the C-121 Super Constellation; The U. S. Geological Survey, Convair; Texas Instruments, a B-25; Mexican Space Commission, a DC-6, etc. /19

In any event, the cargo and performance of the aircraft will be partly determined by the test sites and their conditions and partly by the instrument complement. Altitude versus velocity curves will be dictated by numerous conditions such as aperture of the collector (lens or antenna), field of view and view scanned by the sensor. When multiple sensing is done it will be necessary to arrive at a compromise solution between the altitude and the corresponding velocities, depending upon the type of mission, required data and relative sensitivity of the sensors used.

In case of systematic coverage of test areas by overflight, an absence of adequate navigational instrumentation will require marking of the terrain, especially for night flights, and use of a primary instrument (such as a course indicator for example).

TABLE III - FIELD INSTRUMENTATION AGRICULTURE AND GEOLOGY

With cost indication in THOUSANDS OF DOLLARS

Item	Instruments	Geological Survey		Dept. of Agriculture	
1	Thermal Radiometers	Barnes (2)	14	Barnes PRT-5	14
2	Field Spectrometer (0.3 to 2.5μ)	Beckman, Block	50		50
3	Field Spectrometer (2.5 to 14μ)	Beckman, Block	60		60
4	Magnetic Tape recorders, 7 tracks			(2)	18
5	Recorders-dual pen	Ampex, Honeywell	45	(2)	12
6	Storage oscilloscope				3
7	IR reference for calibration	Beckman, Block	2		2
8	Infrared camera			Barnes T-5A	28
9	Pyroheliometer		3		
10	IR Thermistor		1		
11	Neutron Probe	Nuclear Chicago	4		
12	Meteorological Instrumentation	-	10		10
13	Automatic meteorological data recording system 20 channels				22
14	UHF Radio System				14
15	Mobile instrumentation pick-up truck with camper for spectrometers recording				5
16	Mobile instrumentation trailer for data handling system				4
	Total in thousands of dollars		189		242

V - Field Instrumentation

For the establishment of the "truth in soil", the American organizations suggested to CNAE the instruments appearing in Tables III and IV. It suffices to say, in conformance to comments made at the Willow Run Center of The University of Michigan and in other places, that as far as field spectrometers are concerned, Items 2 and 3 of Table III are the most expensive and do not lend themselves to a convenient use for the required ends. All of them have serious problems in regards to operational speed, field of vision, size and weight, power sources, etc. Note that all of the recording instruments (Items 4, 5 and 6) are primarily destined for spectrometers, just as is the truck of Item 15. At Willow Run there exists a "Beckman Microspec Spectrometer" which was modified by the University of Michigan for employing a ge Hg detector and destined for capturing spectral data of external targets of interest. This adaptation produces the cheapest spectrometer offered by Beckman. /22

Further, Dr. Arch Park, project coordinator for the Department of Agriculture, informs that the given amounts correspond to the cost of the order issued by his department and also include development cost; hence he believes that the prices of copies should be 20 to 30 % cheaper.

It is to be noted through the recommendation of the American organizations, which are principal users of the sensors in Agriculture, Sylviculture, Geography, Geology and Hydrology, that the principal effort is clearly oriented to the spectral band beginning at 0.3 microns (approximately UV), passing through visible and reaching 15 microns in the infrared. Radiometry in the microwave band is provided for only in the section on Oceanography. Studies of radar applications appear to have an empirical character of a simple search for correlations between obtained images and the known "truth in soil" derived by traditional methods.

TABLE IV - SHIP INSTRUMENTATION /21

OCEANOGRAPHY

Item	Instrument	$
1.	Wave Staff (Atlantic Research)	10,000
2.	Salinity Temperature Depth Recorder	30,000
3.	IR Thermometer (Barnes)	2,000
4.	Bathyscaph Thermograph (Packard Electric)	10,000
5.	Thermistor	1,000
6.	Surface Salinograph (Bisset-Burnham)	6,000
7.	Photo Cameras	2,000
8.	Near Surface MW Radiometer	10,000
	Total	71,000

VI - Laboratory Instrumentation

Basic research studies in the laboratory will coherently follow the same line of action. In Weslaco, Texas, fundamental agricultural sensorial studies are realized with

a) Beckman Spectrophotometer DK-2A (0.3 to 2.5 microns) transmission, or absorption of a sample with a standard. The result is registered by a continuous recorder itemizing the percentage of transmission, reflection or absorption as a function of the wavelength. Subsequently the results are digitized and punched on tape, using Datex, for the purpose of processing on Purdue University computers. /23

Besides the described instrument, there are others as follows:

b) Densitometer - a photometer of high sensitivity designed for measuring optical densities by means of photographic transparencies. The instruments used are Welch Densichron Model 451-34 and Model 3853D - Transmission Light Source. Approx. cost is $900.

c) Isodensitometer - a high speed instrument, for exploratory sweeping, reading optical density in all parts of a film and plotting the results on a density map. It is a combination of a Tech/Ops Isodensitracer Model A 300 with a Joyce Loebel & Co. Ltd. Double-Beam Recording Microdensitometer. Approx. cost is $51,000.

d) Foil thickness meter - an instrument with a digital readout of foil thickness, in inches x 10^{-3}, when a foil or other material is placed in a special support. It consists of a Linear Transducer (Daytronic Model DS 200) working in conjunction with a Daytronic Model 201 B AC to DC Modulator and a Digital Voltmeter (Hewlett Packard Model 405 BR). Approx. cost is $1,500.

e) X-Y Recorder - for cartesian coordinate plotting of AC or DC signals. Also contains a device for plotting a variable in relation to time. Approx. cost is $2,000.

In Willow Run Center there exists a most versatile instrumentation for basic studies of most diverse subjects such as agriculture, geology, and even questions of military nature. This instrumentation includes:

a) A Beckman Spectrophotometer DK2 (0.3 to 2.5 microns), /24
b) A Spectrometer, of local construction (0.3 to 14 microns) for bidirectional measurements (the Beckman is unidirectional)
c) A Perkin Elmer Spectrometer 21 (2 to 14 microns)
d) A black body reference, collimators, etc.

It is at that center that a strong recommendation was made in favor of the Cary Spectrophotometer, model 90, for use over the entire band of 0.3 to 22 microns; however, the Brazilian representative of Cary affirms that, given the difficulties of the monochromator device, he does not supply models 90 any more but only the original version (2.5 to 22 microns).

NASA, in its paper on the provision of means for aerial survey and distribution of collected data, does not require laboratories for basic application studies and avoids same in the participation of selection and implementation of test areas. Only recently (and for obvious reasons) was it decided to attack this last problem of significantly reducing the quantity of test areas, of which these are now 200. It was also decided to standardize the equipment for the acquisition of "truth in soil" data, thereby making it compatible with instrumentation of NASA aircrafts and general use, considering the vehicles which most use the instrumentation.

VII - Data Processing Equipment

For the American program the M.S.C. was assigned the task of supplying its researchers with data collected by its aircraft, processed in a manner defined by them, because that Center has at its disposal data processing equipment of great versatility. /25

Electronic Processing

Ground or airborne recording of data on magnetic tape, in direct, P.C.M. or F.M. form, after a quick verification at the Electronic Instrumentation Systems Division, is sent to the Computation Center where it is converted to form suitable for entry into digital computers. The digital computer is a CDC 3800 with 60K internal memory, equipped with magnetic tapes, drum memory, two printers at 1000 lines per minute, card reader for 2000 cards and a card punch. A CDC 3200 is utilized as a control unit for FM - analog-digital conversion.

In addition to this basic equipment, the following is employed:
- Equipment for tape duplication
- " " signal conditioning
- " " decommutation
- " " analog-digital conversion

The Computation Center for the Agricultural Research Laboratory of Purdue University is equipped with an IBM 360/44 with eight (8) magnetic tapes, 1000 lines per minute printer, card reader/puncher and magnetic disc. This complement processes agricultural data incoming from Weslaco.

Photographic Processing

The photographic laboratory of the M.S.C., operated through a contract with Data Corporation, processes the following types of films, all made by Eastman Kodak: Ektachrome, Ektachrome IR, Panchromatic, Black and White IR, Aeroneg Color and Aeroneg Color IR, sizes 35mm to 9-1/2"; these can be reproduced in the following manner: black and white in a paper copy form, the usual positive transparencies, or 9-1/2" glass plaques, rectified copies, photomosaics, copies with electronically balanced contrast (dodged), etc.; color films in a paper copy form, C and R types, duplicates of positive transparencies, internegatives, etc. For these ends the following heavy equipment is used: /26

- Equipment for film development: Black and White Versamat
- Equipment for film development: Color Versamat
- Niagara Copier

- Zeiss SEG V rectifier
- Logetronic Mark II plate copier
- Logetronic SP. 10/70 B roll copier
- EK4C copy processor, Types R and 4A

Total cost of this equipment is estimated at $200, 000.

For field use (partial color film processing included) NASA has portable diffusion processors manufactured by H. B. Singer.

Expended Supplies

For preliminary planning, the following data can be used.
Aircraft activity, assuming flights every second week, results in: /27
6 missions/trimester
5 days/mission
1 flight/useful day
3 hours/flight
1 hour of data collection/3 flight hours

Despite the fact that these figures lead to a total of 300 flight hours per year, in practice a round figure of 300 hours can be used, with 100 hours of useful data collection time.

For example, admitting a consumption of (1) one reel of magnetic tape with 14 channels and (5) five rolls of 9" x 9" by 75 feet of film per flight and knowing that one reel of magnetic tape costs 50 to 60 dollars and that photographic film is sold for $0.75 to 1.00 per foot, annual expenditures may reach $6, 000 and $37, 500, respectively, for these two items; this cost is sufficiently significant.

Another expended item of high cost (and difficult procurement) is liquid helium, normally utilized in the U. S. A. as a cryogenic medium in detectors for the 8-14 micron band, whose cost is estimated at $10 to 15/liter. However, there exists a French mercury and cadmium Telluride detector which works in the 2-14 micron band and utilizes nitrogen (listed at 30 cents/liter) instead of helium. It is remarked, in passing, that the utilization of these liquefied gases, in infrared sensors, is an important factor in the limitation of the useful flight time of the aircraft. /28

VIII - Distribution of Tasks

For the purpose of evaluating the intensity and extension of the projected research activities, keeping in mind the desired practical results (of indisputable social and economic interest), Table VI shows application areas which are being studied by the Americans. It is judged that the underlined items in the table are of immediate interest to the project under direct supervision of CNAE.

As stated before, the adopted composition of the research team, in the U. S. phase, assumes that work will be done in all disciplines mentioned in the plan of cooperation. It also assumes that the small number of technicians, from each specialty, that was possible to send for study abroad, will receive from organizations directly cooperating in the project an adequate support, primarily in the areas dealing with field studies including selection and development of test areas. In this sense, effective support is expected from the following organizations:

a) In soil resources (Agriculture, Sylviculture, and Geography):
Agronomy Institute of Campinas, the Secretary of Agriculture of the State of São Paulo;

b) In mineral resources (Geology, Hydrology, and Cartography):
Department of National Production of Minerals and National Waters and Energy, the Department of Mines and Energy, located in Rio de Janeiro;

c) In sea resources (Oceanography and Hydrography):
Directorate of Hydrography and Navigation, The Department of Navy, located in Rio de Janeiro. /29

TABLE VI

APPLICATION AREAS

1. Agriculture
   a. Plantation control
   b. Plant pathology
   c. Soil chemistry
   d. Control of basins for drainage
   e. Water and soil engineering

2. Sylviculture
   a. Forest inventory
   b. Detection of forest fires
   c. Energetic equilibrium in forest areas
   d. Determination of total terrestrial biomass
   (gross weight of live matter, of vegetal and animal origin, can be expressed as a total dry weight or as a quantity of fixed carbon.)

3. Geology
   a. Basic geological mapping
   b. Prospecting of mineral resources
   c. General and engineering geology
   d. Global forecasting service

4. Hydrology
   a. Measures of terrestrial ice and snow
   b. Ice in rivers and lakes, inundation areas
   c. Surface temperatures of lakes and currents
   d. Vegetation, use of the earth and origin of sedimentation in currents
   e. Geomorphology of basins
   f. Detection of frozen and non-frozen soil
   g. Evaporation, transpiration and energetic equilibrium
   h. Determination of soil humidity

5. Geography and Cartography
   a. Earth use: Distribution of human activity over the earth
   b. Relations of human means; modalities of the use of resources
   c. Physical geography
   d. Global mapping
   e. Basic topographic mapping

6. Oceanography
   a. Surface temperatures of the sea
   b. Ocean currents
   c. Marine biology
   d. Ocean waves
   e. Ice in the sea
   f. Coastal geography
   g. Distribution of atmospheric components
   h. Interrogation of ships and buoys and retransmission of data

   -- Underlined items are judged to be of immediate interest to the project. /30

It is through these organizations that is expected to achieve an in-depth approach and expansion of the project through various fields of specialization.

The indicated grouping of disciplines, in general, is parallel to the American program whose user agencies are:

a) In Agriculture and Sylviculture, the U.S. Department of Agriculture
b) In Geology, Hydrology, Geography and Cartography, the U.S. Geological Survey (U.S.G.S.)
c) In Oceanography and Commercial Fishing, the U.S. Naval Oceanographic Office (NAVOCEANO)

In addition to the responsibility of general project coordination, CNAE will be required to obtain, instrument, operate and maintain the following installations, equipments and services:

1 - Office for Planning and Control
2 - Laboratory for Basic Studies
3 - Instrumentation and Data Analysis Laboratory
4 - Aircraft for Aerial Sensing
5 - Laboratory for Photographic Processing
6 - Computation Center
7 - Data Bank
8 - Vehicle with Instrumentation for Field Studies

NASA's principal responsibility in the American program is to demonstrate what can be done; the users state what is necessary to do, how it should be done and what is the cost of doing it. NASA does not provide laboratories for basic studies in remote sensing (item 2 above) and its instrumentation laboratores are limited to calibration, maintenance and possible repairs (item 3 above). It allows application studies to be done by the user organizations and their collaborators, /31
and distributes research and development of sensors through the following

specializing teams, where a cooperation takes place between the user, cultural or educational entities and the appropriate private industry:

- Photographic instrumentation (Dr. A. P. Colvocoresses, from NASA Headquarters)
- Infrared instrumentation (Dr. R. J. P. Lyon, from Stanford University)
- Ultraviolet instrumentation (Mr. William Hemphill, U. S. G. S.)
- Radar instrumentation (Dr. R. K. Moore, University of Kansas)
- Microwave instrumentation (Mr. Frank Barath, Jet Propulsion Laboratory).

Evidently, user's agents are invited to participate in all program stages, including the level where decisions are made on basic directives.

At NASA, the organization responsible for Earth Resources Aircraft Program (ERAP), is the Manned Spacecraft Center, with the Directorate of Sciences and Applications of this center being responsible for the general management, planning and control of all project phases; it delegates these responsibilities to a Project Manager of "Test and Operations Office (TOO)." This office has two other subordinates: one which deals with missions and data management and another with equipment (see item 1).

Executive tasks are distributed through specialized sectors of general support already in existence at M. S. C. for its principal mission relative to manned spacecrafts.

In this manner, in the Directorate of Engineering and Development, the Instrumentation and Electronic Systems Division (IESD) is responsible for various sensing systems (excepting certain photographic equipment) and provides on board operators (see item 3); the Information Systems Division (ISD) is responsible for the compatibility between systems of on board data acquisition and the /32
installations for data reduction by MSC (see item 3); and the Computation and Analysis Division (CAAD) is responsible for the reduction of magnetic tape data (see item 6).

In the Directorate of Flight Crew Operations, the Aircraft Operations Office (AOO) has the responsibility for modifying, operating, and maintaining the aircrafts (see item 4). In the Directorate of Administration the Photographic Technology Laboratory (PTL) (operated through a contract with Data Corp.) is responsible for the specification and all film processing, supply of film and processing materials for mission support and photographic equipment of current use; it also supplies photographers for aerial missions (see item 5). In the same Directorate, the Management Services Division administers the Data Bank (see item 7).

As explained previously, for the purpose of standardizing instrumentation for the acquisition of "truth in soil" data, making it compatible with aircraft instrumentation and adapting it for general use, NASA is contemplating the construction of those vehicles in which the instrumentation is concentrated (see item 8).

In conformance to the above account, CNAE seeks to reproduce, on a highly reduced scale, the model whose efficiency appears to be proved.

It is essential that with a small team of researchers it be possible to attain, in a short time, significant results and that the initial tasks of this team be defined and distributed in conformance with the following criteria:

a) Orient the application studies toward definite problem areas and attempt to develop plans for a minimal program, avoiding extensions of work to correlated activities already satisfactorily implanted in the country;

b) Restrict sensing in the electromagnetic spectral bands, given their degree /33
of applicability, to those indicating greatest promise, without forgetting the advantages of overall spectral survey;

c) Distribute trained personnel for specific tasks of the minimal program, even at the cost of ignoring their specialty, and avoiding their dispersion to support activities which can be done by others.

Table VI presents a list of application areas being investigated by American organizations representing the users. Underlined items are judged, as a first approximation, to be of most immediate interest to CNAE's program. It remains to identify which of them must be considered as problem areas.

Table VII shows priorities of the use of remote sensing instrumentation for various application sectors; it is a simple conjecture based on revised passive information, and also on the consideration, in each sector, of application areas being of most immediate interest for the program. Last column shows a suggestion of the order of priority for the entire project.

Without searching for specific application areas for various disciplines, it appears to be evident that, as a starting point, the aerial sensing system must include photographic and infrared sensors, exploring the 0.3 to 14 micron band. Later, it will be possible to use microwave frequencies, including a sidelooking radar whose applicability in geological mapping is incontrovertible. For photographic sensors it will suffice to have, initially, a cluster of multi-band cameras, since the project does not contemplate work on aerial photography for purposes of topographical survey (which is the basic use of metric cameras). Among infrared sensors the imager (display), preferably with two channels, stands out. Appendices A and B contain descriptive data on the two sensors. /35

Concerning radar, unfortunately only vague information is in existence. The first information concerning NASA's equipment on Lockheed P3A only mentions a Sidelooking Radar (Philco, Motorola, Goodyear), whose price is $300,000, with an observation that this quantity reflects modification costs only, and that a typical "Sidelooking Radar" will cost about $750,000. More recent information mentions a Philco at 16.5 GHz (K Band, 2.25 cm), costing $250,000, to become operational in August of this year. A U.S. Naval Oceanographic Office publication titled "Spacecraft Oceanography Project," 1967 Edition, informs that the mapping radar of that plane, Aeromutronic DPD-2, will be sidelooking and of high resolution, low weight (75 kg) and with a synthetic aperture.

TABLE VII

APPLICATION FIELD (DISCIPLINES)	AGRICULTURE AND SYLVICULTURE	GEOGRAPHY AND CARTOGRAPHY	GEOLOGY	HYDROLOGY	OCEAN-OG-RAPHY	PRIORITIES IN THE PROGRAM (SUGGESTION)
REMOTE SENSOR INSTRUMENTATION	PRIORITIES RELATIVE TO USE					
PHOTOGRAPHY 1. Metric Cameras 2. Set of Multispectrum Cameras	1	1	1	1	1	1
INFRARED 3. Infrared Radiometer 4. Infrared Spectrometer 5. Infrared Display (Imager)	2	3	3	2	2	2
LASER 6. Laser Altimeter	5	4	5	5	5	5
RADAR 7. Sidelooking Radar 8. Radar Scatterometer	3	2	2	4	4	3
MICROWAVES 9. Microwave Radiometer 10. Microwave Display (Imager)	4	5	4	3	3	4

/34

From the industry we have a Westinghouse brochure (Aerospace Division), offering the presentation of earth surface images (obtained with an aerial side-looking radar with high resolution) on the basis of dollars per square mile and the interpretation of these images (left to client's discretion); this relates to applications in geological surveys, exploration for petroleum and minerals, administration of mineral resources, agricultural surveys and mapping of ice on the seas. The instrument in use is an AN/APQ-97 radar, developed for the U.S. Army Electronics Command. There exists a project named RAMP (Radar Mapping in Panama), carried out by the U.S. Army Corps of Engineers, utilizing this radar, in a type YEA-3A plane. It aims at developing a basic map in an area with a known history of continuously inclement weather.

In summary, for the first stage, sensory instrumentation for the aircraft would consist of:

1. A cluster of photographic cameras (4)
2. Infrared imager (display), with 2 channels /36

And, for the second stage, of:

3. Sidelooking radar

For other activities, the equipment to be selected would have to be able to operate with this aerial instrumentation. In particular, the weight, configuration and volume of this aerial instrumentation and its accessories, and the number of required technicians for its in-flight operation will obviously be basic factors for the determination of the cargo and performance of the aircraft, to which must be added considerations related to locality and conditions of the test areas.

As for the distribution of personnel for specific tasks, on a first approximation, the specialists trained in the United States could be divided in the following indicated manner:

- Office of Planning and Control - (Coordinates Aerial Missions)	(1) Geographer
- Laboratory for Basic Studies -	(1) Agronomist (1) Geologist (1) Oceanographer
- Laboratory for Sensory Instrumentation and Analysis of Data -	(3) Electronic Engineers
- Studies at Test Areas - (Includes Managers for Soil, Mineral and Sea Resources)	(1) Agronomist (1) Geologist (1) Hydrologist (1) Oceanographer (1) Geophysicist
- Computation Center -	(1) Electronic Engineer

The Aircraft, Photographic Laboratory and the Data Bank would be staffed with personnel not trained in the United States.

IX - Test Areas

In the data on test areas, presented below, the following characteristics were sought:

a) That the test area, selected as a representative of a given specific scientific or technical interest, already has yielded sufficient knowledge concerning these typical characteristics of interest;

b) That the selected locations:

1) be a reasonable distance from the coordinating organs and laboratories;

2) be relatively easily accessible to the researchers of the "truth in soil" program;

3) be in a region containing an adequate ground support for aircrafts.

The CNAE establishment, where the central organ of the Project will be housed, is located in São José dos Campos, State of São Paulo, 84 km from the city of São Paulo and 312 km from Rio de Janeiro by a paved four (4) lane highway. The airport of that city is being enlarged so that jet airplanes will be able to operate from it.

Agriculture

Santa Eliza Farm, in Campinas

The Agronomy Institute of Campinas suggests that the "Theodureto de Camargo" Experimental Station, better known as the "Santa Eliza Farm," is an adequate test area for Agricultural studies. /38

This station, with an area of 710 hectares (1750 acres), is the principal station of the Agronomy Institute of Campinas which has a total of 16 experimental stations. It is the seat of various sections of the Institute, primarily those dealing with cultivation research.

a) Location

Three to four km from the city of Campinas, with part inside the urban perimeter, and one (1) km from the Institute building.

b) Agricultural diversification

Being the largest station, it presents a major diversification of cultivation. It is highly favorable for studies of forms, "thatch," spacing, texture, and structure. However, there exist some disadvantages for the study of cultivation in large areas.

c) Soils and geology

It has, in addition to a geological survey, a detailed soil and conservation survey.

d) Climatology

It has a Meteorologic Station of Class 1A, with local records dating 50 years back; it is the most complete of the Institute's chain and also performs work on microclimate.

e) Campinas

The city of Campinas has about 300,000 inhabitants, two airports, one international (Viracopos) and the other, known as the Amarais, located one (1) km from the Experimental Station. Amarais has unpaved runways.

This city is 100 km from São Paulo and linked to it by a paved 4 lane highway. /39

"Agua Preta" Research Field, in Pindamonhaugaba

For Agricultural studies related to irrigation and drainage, the same Institute suggested the utilization of the "Agua Preta" Experimental Field which belongs to the Department of Waters and Electric Energy of the State of São Paulo, an organization working directly with the Agronomy Institute of Campinas. This Field is part of an area protected by dikes, meandering passages and has a pump house for irrigation and drainage. This area, therefore, is fully drained and with irrigation; the same is true of all adjacent properties in an integrated plan. Almost all of its work is dedicated to rice, but there exist experiments in pasture, and cultivation of potatoes, tomatoes, etc.

The Field has detailed soil surveys and a small rain-measuring station. It has housing for technicians.

It is located only 4 km from Pindamonhangaba city, which is about 60 km from CNAE (which is also situated in the Paraiba valley).

For management unification reasons, it is proposed that for sensor application studies in Sylviculture and Geography (the disciplines that appear in the Project grouped with Agriculture, under "Soil Resources") the following be done: the test areas should be chosen in such a manner as to allow (if at all possible) by virtue of their location collection of data by simple extension to missions programmed primarily for Agriculture, or vice-versa; and, similarly, one should be able to collect specific data in a manner allowing their possible use by researchers of other specialties. In this manner, one should select the following test areas: /40

Sylviculture

Areas in proximity of Campinas are suggested, where extensive eucalyptus plantations are in existence. These already were objects of photo-interpretive studies by the Institute's agronomist who is a NASA intern.

Geography

The terrain band beginning at the city of São Paulo and extending NW up to Rio Claro is suggested with Via Anhanguera as the axis; in this manner, it will include Campinas and the above mentioned eucalyptus grove. There can be no doubts as to the value of this region for the study of standard uses of the soil and of its dynamic transformations. The actual situation of the Santa Eliza Farm in relation to the urban area of Campinas corroborates this statement.

The suggested band of terrain constitutes, in fact, a multi-disciplinary test area, which in regards to Agriculture remedies the deficiency of the Santa Eliza Farm concerning the study of cultivation in large areas.

For preliminary studies of test areas for Geology and Hydrology (Mineral Resources) and Oceanography-Hydrography (Sea Resources) it is suggested to consider the following regions for the selection of sites: /41

Geology

Ferriferous Quadrilateral

There exist detailed geological studies of this area, of approximately 7000 km^2, located in the SE region of the State of Minas Gerais; these studies were made through an agreement between Brazil and the United States. In Brazil, the study program was under the responsibility of the Division of Mineral Resources of the National Department of Mineral Production (formerly of the Department of Agriculture and today of the Department of Mines and Energy). In the United States the program was administered by the State Department through the Institute of Inter-American Affairs. The results of these studies are recorded in a collection of reports, published by the U.S. Department of the Interior, titled "Geological Survey Professional Paper 341-A, B, etc." and dated beginning with 1962.

The city of Belo Horizonte is in an area surrounded by the quadrilateral and from its northern limit is 445 and 576 km from Rio de Janeiro and São Paulo, respectively (by paved highway). This city has an airport for domestic airlines.

Hydrology

The Paraiba River Basin

The hydrologic knowledge of this basin is already sufficient to permit a scientific support for aerial missions of studies in a discipline yet having limited sensorial application (but which may come to be important). /42

The reason for selection of the "Agua Preta" Experimental Field, already mentioned during agricultural considerations, and located at the banks of that river, is thus reinforced.

Oceanography and Hydrography

Waters of the Brazilian Meridional Shore

The oceanographic knowledge about this area will allow one to take advantage of the existing images, taken by various remote sensors during specially programmed missions.

High altitude infrared images could mark the temperature contrasts that characterize contours of the Brazilian Current, on the east and south shore, and the Current of Malvinas (which invades our meridional shores during winter). The localization of such contours is important for navigation and maritime rescue, for fishing and meteorology (warming or colling of the near-ground air, and, consequently its destabilization and stabilization). Possibly, cloud images, regularly received by satellite at CNAE, will corroborate such contours.

Lower altitude photographs, whether natural color or infrared, should define those sea spots which are produced by drainages (Lagoons of the Rio Grande of Sul, Cananéia Lagoon System, etc.) or by plankton concentrations. Once the nature of these spots is oceanographically determined (by sampling), it will per- /43 mit the determination of not only the proportion of such elements in the composition of the so called "littoral water" but, through the analysis of spot extension, the determination of coefficients of physical diffusion which are particularly important for planning the introduction of effluents (radioactive, sanitary sewers) into the ocean.

Besides, we know that multi-spectrum photographic sensors can perceive bottom irregularities in shallow zones, as well as obtain a better definition of coastal line.

X - Equipment for Project Implementation

As a first attempt, the identification of a prime decisive factor, for the selection of instruments to be utilized by different project activities, was sought.

In Part VIII it was suggested that the initial aerial sensory system consist only of the following gear:

1 - A cluster of photographic cameras
2 - An infrared imager (display), with 2 channels
3 - Sidelooking radar

Foreseeing a possibility that the delivery of the radar would be considerably longer than that of the first two items, it was stated that: the system could be completed in two stages (even with provisions to initiate the acquisitions simultaneously).

The acquisition of gear for other activities, obviously, will depend upon the choice of basic aerial sensory system, of its accessories, characteristics of its operation, and, even, its future expansion. This is particularly critical for the /44 determination of the aircraft lift and performance, which will be strongly influenced by the antenna configuration of the high resolution radar available for it.

The instrumentation for studies in the laboratory and in the field concerning "truth in soil" has its principal interest, frankly, directed to spectral band comprising wavelengths 0.3 to 14 microns. Inside this band the selection of instruments will depend upon a basic decision: are studies limited to shorter waves (up to about 2.5 microns) sufficient or are more complete investigations, encompassing the entire band, required? This decision is made following the example set by the Remote Sensing Laboratory of The Experimental Farm at Weslaco. It is believed that if the studies of the "truth in soil" are to be correlated with the data obtained with an infrared imager, of two channels, they need be done in a manner compatible with this instrument, i.e., over the entire band.

We grant that at higher frequencies (wavelengths less than about 3.5 microns) infrared radiation captured from the soil is predominantly reflected solar energy. Only at lower frequencies will the emission be predominantly thermal, i.e., that of soil objects.

The non-utilization of 9" metric cameras will considerably reduce the size of installations for photographic processing which will be required to copy and develop color film of at most 70 mm (Ektachrome or Aeroneg).

It is to be remembered that the generalized use of optical equipment by the project occasions the necessity of a specialized office, which may be part of an appropriate photographic laboratory. /45

As far as electronic processing equipment is concerned, the key point appears to be the utilization of an apparatus for automatic reading of photographic film density, equipped with an analog-digital converter. This is analogous to the exhibition of data, detected by sensors, by means of images.

On the basis of these ideas and information supplied by the NASA trainees, preliminary lists of instruments were prepared for each activity sector. These lists are presented in appendices C, D, etc.

XI - Programming

CNAE's research team will conclude, at the beginning of August, a six month apprenticeship at NASA. The apprenticeship included a 12 week course on basic theory of sensors, their types and possible uses, and the processing and interpretation of data collected with them. Presently, these researchers, separated by specialties, are visiting laboratoreis and test areas of the American program. The period of travel, initiated on May 20, will be six weeks. During this time, NASA's Convair will be available for data collection missions related to the apprenticeship.

In accordance with the Cooperation Plan the month of July will be used (using the experience of CNAE's researchers and the help of their American colleagues, as well as this Program Outline) to deliberate on the following subjects:

1 - Preliminary selection of test areas /46
2 - Selection of sensory instrumentation
   a) Types, loads and costs

b) Commercial availability and suppliers
c) Accessories, spares and supplies
d) Initial provisions for their acquisition

3 - Aircraft selection
a) Type, lift and performance
b) Useful cargo
c) Delivery date and cost
d) Accessories and spares
e) Installation responsibility and test of sensory instrumentation
f) Initial provisions for its acquisition

4 - Selection of instrumentation for the "truth in soil" program
a) Types, loads and costs
b) Commercial availability and suppliers
c) Accessories, spares and supplies
d) Initial provisions for their acquisition

5 - Data processing equipment selection
a) Data to be processed
b) Procedures for processing
c) Procedures for divulgence
d) As in item 4 above (photography and electronic computation)

6 - Special documentation requirements

7 - Common interests of the cooperating teams of the project /47

8 - Revision of planning for subsequent phases of the Plan of Cooperation

9 - Initial planning for aircraft missions (NASA and CNAE)

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